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14. ABSTRACT

We attempted to quantify potential individual exposures to Agent Orange (to include its trace dioxin contaminant) experienced by persons (e.g., aircrew, passengers) who worked on or travelled in UC-123 aircraft between 1972 and 1982. After an extensive search of the scientific and technical literature, review of the available sampling data, an attempt to employ modeling to extrapolate exposures, and an assessment of the feasibility of conducting epidemiological studies, we concluded the existing information and data are inadequate to allow for accurate quantitative estimates of individual exposures. We then considered the probability of harmful exposures in UC-123 exposure groups (i.e., occupational and general populations) based on the nature and environment of the material sampled, the expected characteristics of dried Agent Orange residue, and the conditions of general exposure. At this time, we conclude that the discernable information suggests the potential Agent Orange exposures for both groups (who were in contact with the UC-123 aircraft between 1972 and 1982) were unlikely to have exceeded acceptable regulatory standards or to have predisposed persons in either group to experience future adverse outcomes.

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DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE OHIO 45433

MEMORANDUM FOR AFMSA/SG3

FROM: USAFSAM/CC

SUBJECT: Consultative Letter, AFRL-SA-WP-CL-2012-0052, UC-123 Agent Orange Exposure Assessment, Post-Vietnam (1972-1982)

1. INTRODUCTION

a. *Purpose*: Headquarters Air Force Medical Support Agency (AFMSA/SG3) requested the United States Air Force School of Aerospace Medicine (USAFSAM) conduct an exposure assessment related to Agent Orange, also referred to as Herbicide Orange (HO), for legacy UC-123 aircraft used after support of Operation RANCH HAND in Vietnam. This includes the time period from 1972 through 1982.

b. *Executive Summary*: We attempted to quantify potential individual exposures to Agent Orange (to include its trace dioxin contaminant) experienced by persons (e.g., aircrew, passengers) who worked on or travelled in UC-123 aircraft between 1972 and 1982. After an extensive search of the scientific and technical literature, review of the available sampling data, an attempt to employ modeling to extrapolate exposures, and an assessment of the feasibility of conducting epidemiological studies; we concluded the existing information and data are inadequate to allow for accurate quantitative estimates of individual exposures. We then considered the probability of harmful exposures in UC-123 exposure groups (i.e., occupational and general populations) based on the nature and environment of the material sampled, the expected characteristics of dried Agent Orange residue, and the conditions of general exposure. At this time, we conclude that the discernable information suggests the potential Agent Orange exposures for both groups (who were in contact with the UC-123 aircraft between 1972 and 1982) were unlikely to have exceeded acceptable regulatory standards or to have predisposed persons in either group to experience future adverse outcomes.

(1) *Occupational Group:* The occupational group consists of aircrew members and maintainers. Occupational exposures are generally assessed utilizing personal air sampling methods. No reference to personal air sampling was found in the document search; however, results from area air samples collected from within the UC-123 aircraft were found. Using area air samples as a surrogate for personal air sampling, all reported air samples were within acceptable occupational standards for components of HO.

(2) *General Population Group:* The general population encompasses all nonoccupational individuals, including medical evacuation personnel, paratroopers, and other such passengers. For the general population, the available criterion published by the U.S. Environmental

Protection Agency (EPA) and World Health Organization (WHO) are based upon lifetime ingestion with regards to food and water. Ingestion of HO components would occur from hand–to-mouth activities or eating food that came in contact with a contaminated surface. Given a lifetime is equivalent to 25,000 days and the small number of occurrences of hand-to-mouth/ eating of contaminated food, the possible exposures are considered incidental and the health risk negligible.

c. *Assessment Limitations/Delimitations:* This assessment only addresses exposures that took place after the Vietnam War. It is assumed the HO spraying equipment/storage tanks were removed from each UC-123 aircraft prior to any post-Vietnam utilization; therefore, any exposure to HO components would have come from residual that may have remained in the aircraft. An additional assumption is the amount and composition of residual HO components in the UC-123 did not significantly change over time following the 1972 to 1982 time period.

2. DOCUMENT REVIEW

a. *Background*: To perform a health risk assessment, exposure data, routes of entry to the body, population(s) at risk, and dose-response relationships were evaluated. An extensive survey was conducted for post-Operation RANCH HAND UC-123 information required to perform an exposure assessment for HO. HO is a term used to denote a defoliant that is a mixture of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Dioxin, more specifically 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), is a trace contaminant formed during manufacturing of HO.

b. *Populations*: The potential exposure groups were defined as occupational and general population. The occupational group includes those individuals who worked with the UC-123 aircraft, predominantly flight crew and maintainers. The general population group includes all individuals who are not classified as part of the occupational group. This includes individuals who flew in the UC-123, such as medical evacuation patients and medical support personnel, paratroopers, and passengers.

c. *Exposure*: The available exposure data are presented in the attachment. Inhalation is the predominant route of entry when determining occupational exposures and is most accurately assessed using personal breathing air monitoring. Only area air sample results were found in the literature; these results were used as a surrogate for personal air sampling. Skin contact with contaminants can lead to dermal absorption and secondary ingestion from hand-to-mouth behavior. With respect to the occupational setting, no consensus of the occupational health/ industrial hygiene community exists in ascribing exposure from surface contamination. For general population health, ingestion is normally assessed in terms of contaminant found in food and water sources.

d. *Occupational Standards*: The inhalation occupational exposure limit (OEL) for both 2,4-D and 2,4,5-T is a time-weighted average of 10 mg/m^3 based on an 8-hour-per-day, 5-day- per-week exposure and has not changed since 1979. Dioxin has many chemical forms; TCDD is considered the most toxic and is most often evaluated in exposure assessments. No quantified

OELs for TCDD are established; since dioxin is labeled a human carcinogen, professional standard of practice is to control exposure to the "lowest feasible concentration."[1]

e. *General Population Standards*: The EPA[2] and WHO[3] establish standards based on continuous exposure over a lifetime. For 2,4-D and 2,4,5-T, the EPA has established an oral reference dose of 0.01 mg/kg-day, while the WHO only has a drinking water standard for these herbicides without listing a specific oral reference dose. As of February 2012, the EPA oral reference dose for TCDD is 0.7 pg/kg-day while the WHO has a "Provisional Tolerable Monthly Intake" of 70 pg/kg-month for dioxin that equates to 2.3 pg/kg-day.

f. *Epidemiology*: The Public Health Department's Epidemiology Consult Service (USAFSAM/PHR) found no known or well-described cohorts of post-Operation RANCH HAND UC-123 aircrews and/or maintainers. In addition, USAFSAM/PHR was unable to define adequate control groups to allow morbidity/mortality rate comparisons with the general population. Therefore, the necessary information to perform such comparisons for post-Vietnam UC-123 crews is extremely unlikely ever to become available.

3. DISCUSSION

a. Document reviews discovered only a few area air samples and no personal air samples for HO components. Methods to quantify occupational exposure retrospectively require using assumptions that introduce a significant level of uncertainty into the exposure assessment. Further confounding the issue is the Occupational Safety and Health Administration (OSHA) has no standards that specify industrial surface contamination exposure limits. Surface contamination levels are only used by OSHA to determine the need for procedures to control contamination, not to estimate exposure.

b. Information regarding post-Operation RANCH HAND UC-123 aircraft was extensively searched. Headquarters Air Force Reserve Command, along with those reserve bases known to have UC-123 aircraft in their inventory, was contacted for historical information. The Army Public Health Command was also consulted for Operation RANCH HAND-related information. This search revealed six area air sampling events for herbicides in UC-123 aircraft occurring between the years 1975 to 2009. Herbicide area air samples were collected in 1979 on one aircraft because of complaints of a noxious smell. This sampling resulted in quantifiable levels of 2,4-D and 2,4,5-T, which are components of the herbicides used during Operation RANCH HAND, plus malathion, which was not an Operation RANCH HAND herbicide; dioxin was not sampled during this assessment. The results of this sampling indicated these chemicals were below the permissible exposure limits and not a health hazard[4]. In 2009, area air was analyzed for 2,4-D, 2,4,5-T, and dioxins in four aircraft with no detectable levels reported. Two bulk samples of a residue were analyzed (in 1975 and 1979) and found to contain small amounts of 2,4-D, 2,4,5-T, and malathion. No analyses for dioxins in the residues were performed.

c. In 1994[5] and 1996[6,7], wipe samples were collected to determine possible risks associated with reclamation, restoration, or disposal of UC-123s post-operational use. In 1994, three wipe samples were collected on the interior surface and one on the exterior surface of a single UC-123 aircraft that was selected as a museum display[5]. The concern was potential airborne risk to

restoration workers from particulates generated during cutting, sanding, and other types of destructive industrial activities. The authors cited a screening level for office workers as a basis for their assessment. Using limited data, the aircraft was labeled "highly contaminated," with the admission that fully characterizing the risk would require additional sampling. The presence of dioxin in the samples was then used for the selection of personal protective equipment requirements related to the unique activity of deconstruction and renovation. Subsequently, two wipe samples were taken in 1996 on stored aircraft slated for resale with positive results for dioxin[6]. As follow-up, additional sampling was conducted, although the samples were only analyzed for 2,4-D and 2,4,5-T and not dioxin[7].

d. The most comprehensive study is the 2009 "Dioxin and Herbicide Characterization of UC-123K Aircraft-Phase I."[8] During this study, 4 of 18 aircraft stored at Davis-Monthan AFB AZ, were wipe sampled for residual constituents of HO. Wipe results for all four aircraft showed levels of 2,4-D and 2,4,5-T below the reported risk-based screening level. Two aircraft were characterized with trace amounts of dioxins, while the other two were labeled as having low levels found on all wipes. The authors concluded that the level of dioxins measured did not represent a concern for personnel performing short-term recycling activities.

e. The 2010 National Academy of Sciences' Institute of Medicine biennial report summarized the inability to accurately assess risk to Vietnam veterans as follows: "The information needed for assigning risk estimates continues to be absent despite concerted efforts to model the exposure of the troops in Vietnam, to measure the serum TCDD concentrations of individual veterans, and to model the dynamics of retention and clearance of TCDD in the human body. Accordingly, several successive Veterans and Agent Orange committees have stated as a general conclusion that, at least for the present, it was not possible to derive quantitative estimates of any increased risks of various adverse health effects that Vietnam veterans may have experienced in association with exposure to the herbicides sprayed in Vietnam. Given the amount of time that has passed since the Vietnam era, the current committee has concluded that the necessary information to perform such estimation for Vietnam veterans is extremely unlikely ever to become available."[9]

4. CONCLUSIONS

a. With the small number of data points, it is not considered legitimately possible to quantify with any degree of certainty the potential human exposure to HO related to the UC-123 aircraft for the 1972-1982 time period. While it is not possible to quantify the potential human exposure to HO related to the UC-123 aircraft, available area air sampling data results for the constituents of HO were within acceptable exposure limits.

b. Dioxin is the primary chemical of concern that drives Operation RANCH HAND exposure assessments. Wipe samples are the only evidence found for dioxin contamination in the historical search and the predominant source of information for 2,4-D and 2,4,5-T. Since no regulatory standard or consensus standard of practice exists in the occupational health profession, application of wipe sampling data to estimate personal occupational exposures is not warranted.

c. Ingestion of the contaminants of concern requires the transfer of contaminant from the surface of the aircraft to the mouth and can occur by a person touching a contaminated surface and then transferring the dioxin with hand-to-mouth activities. Given the limited contact of the general population to the UC-123, any ingestion of contaminants would likely be incidental and considered insignificant in terms of a lifetime dose.

d. With the lack of epidemiological evidence and few sampling results related to HO contamination of the UC-123 aircraft between 1972 and 1982, our assessment of risk is dependent upon the findings of the National Academy of Sciences' Institute of Medicine RANCH HAND studies. It is reasonable to assume that any exposures associated with HO in post-Operation RANCH HAND utilization of the UC-123 would likely be less than exposures associated with HO during Operation RANCH HAND. Consistent with the findings of the National Academy of Sciences' Institute of Medicine biennial report (2010), it is reasonable to conclude that it is not possible to derive quantitative estimates of any increased health risks for those individuals who came into contact with the UC-123 aircraft from 1972 to 1982.

5. Thank you for affording USAFSAM the opportunity to assist you. Please direct additional questions to Col Mark E. Smallwood, DSN 798-3364.

CHRISTIAN R. BENJAMIN
Colonel, USAF, MC, CFS
Commander

Attachment:
Summary of Agent Orange Related Sampling of UC-123 Aircraft from 1975 to Present

References

1. NIOSH Pocket Guide to Hazardous Chemicals, http://www.cdc.gov/niosh/npg/npgd0173.html; accessed on 17 February 2012.

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8. Hill AFB, 2009, *Dioxin and Herbicide Characterization of UC-123K Aircraft-Phase I.*

9. Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides (Eighth Biennial Update); Institute of Medicine, 2010, Veterans and Agent Orange: Update 2010; accessed on 27 Dec 2011 at http://www.nap.edu/catalog.php?record_id=13166.

ATTACHMENT 1

Summary of Agent Orange Related Sampling of UC-123 Aircraft from 1975 to Present

Summary of Agent Orange Related Sampling of UC-123 Aircraft from 1975 to Present					
Year	Sample Type	Analyte	Number of Samples	Result Range	Reference
1975	bulk	2,4-D/2,4,5-T	1	Non-detected	Conway, OEHL 79-59
1975	bulk	Malathion	1	Detected	Conway, OEHL 79-59
1979	ambient air	2,4-D	3	0.108 to 0.234 mg/m^3	Conway, OEHL 79-59
1979	ambient air	2,4,5-T	3	0.135 to 0.194 mg/m^3	Conway, OEHL 79-59
1979	ambient air	Malathion	3	1.701 to 3.051 mg/m^3	Conway, OEHL 79-59
1979	bulk	2,4-D butyl ester	1	< 60 µg/kg	Conway, OEHL 79-59
1979	bulk	2,4-D isooctyl ester	1	~92 µg/kg	Conway, OEHL 79-59
1979	bulk	2,4,5-T butyl ester	1	~149 µg/kg	Conway, OEHL 79-59
1979	bulk	2,4,5-T isooctyl ester	1	< 60 µg/kg	Conway, OEHL 79-59
1979	bulk	Malathion	1	~145 µg/kg	Conway, OEHL 79-59
1994	wipe	dioxin	4	200 to 1400 ng/m^2	Weisman, AL/OE-CL-1994-0203
1996	wipe	2,4-D and 2,4,5-T	14	2.2 to 960 µg per wipe	Porter, AL/OE-CL-1997-0053
1996	wipe	dioxin	2	0.21 to 7.4 ng per wipe	Alta Analytical Laboratory, 1996
2009	wipe	dioxin	32	21.7 to 24.7 ng/m^2 95% UCL	Hill AFB, 2009
2009	wipe	2,4-D	32	781 to 911 $µg/m^2$ 95% UCL	Hill AFB, 2009
2009	wipe	2,4,5-T	32	698 to 815 $µg/m^2$ 95% UCL	Hill AFB, 2009
2009	ambient air	dioxin	4	Non-detected	Hill AFB, 2009
2009	ambient air	2,4-D	4	Non-detected	Hill AFB, 2009
2009	ambient air	2,4,5-T	4	Non-detected	Hill AFB, 2009